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INVESTIGATION OF THE EFFECTS OF EXTERNAL CURRENT SYSTEMS ON THE MAGSAT DATA UTILIZING GRID CELL MODELING TECHNIQUES

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16. Abstract

The overall objective of this effort in support of the Magsat project is to study the feasibility of modeling magnetic fields due to certain electrical currents flowing in the earth's ionosphere and magnetosphere. This second quarterly status and technical progress report discusses efforts devoted to reading Magsat data tapes in preparation for further analysis of the Magsat data. The report also describes a new modeling procedure that is being developed to compute the magnetic fields at satellite orbit due to hypothesized current distributions in the ionosphere and magnetosphere. This technique utilizes a linear current element representation of the large-scale space-current system. Several examples of the model field perturbations computed along hypothetical satellite orbits are shown.

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I. INTRODUCTION

The overall goal of this investigation is to study the feasibility of modeling magnetic fields produced by certain electrical currents flowing in the earth's ionosphere-magnetosphere system. Vector magnetic field measurements from the near-polar obiting Magsat satellite contain, in addition to the main geomagnetic field and crustal anomaly fields, components that arise from these external currents. In meeting the ultimate goals of the Magsat project, it is desirable that the external current effects be identified in the observations, and subsequently separated from the internal field. The objective of this effort will be to determine the capability of a modeling procedure to facilitate the separation of these external and internal components.

The approach of this feasibility study shall be to develop forward modeling procedures through which the magnetic effects of model currents may be derived. It is intended to include, separately, the equatorial electrojet, S_q currents, and the effects due to auroral zone and polar cap currents including the high latitude ionosphere-magnetosphere coupling currents. In each case candidate current systems will be devised and resulting "typical" magnetic field signatures calculated for comparison with Magsat observations. The grid-cell modeling procedures developed by J.L. Kisabeth provide one method for calculating certain of these currents. This as well as other techniques will be evaluated.

II. ACCOMPLISHMENTS DURING REPORTING PERIOD

1. Data Reduction

In the first quarterly report, we reported the development of software programs to read the Magsat Chronicle format data tapes on a U.T.D.

PDP 11/45 computer, and printout either the orbital data alone or both orbital and magnetic field-values from both scalar and vector magnetometers for any specified time period contained on the source tape. The program computes geodetic longitude and latitude, and altitude of the spacecraft and outputs this information along with inertial and magnetic coordinate positions. The magnetic field observations for each second are scanned with maximum, minimum, and average values for each scalar head and each vector component being printed. This software package is now being extended so that selected portions of Magsat data can be stored on disc. Additional data reduction software will access the stored data, subtract a model field, and plot the resultant magnetic component deviations on a high resolution interactive vector graphics terminal. This will permit direct comparisons between the measured magnetic field perturbations and the model results described below.

2. Field Modeling

A technique is being developed to model the magnetic effects at Magsat altitudes due to hypothetical currents in and above the high latitude ionosphere. In this forward modeling technique prototype current systems representing the auroral electrojet and ionospheric polar cap currents as well as the field-aligned currents that link these low altitude currents to the distant magnetosphere are devised. This current system is then represented for computational purposes as an array of linear current elements having finite length and a finite diameter with a pre-determined cross-sectional current density distribution. For each hypothetical observation point the three vector components of the resultant magnetic field are to be computed as a

superposition of the contributions due to each current element in the world-space. The resultant magnetic perturbations for each vector-field component are displayed on a high resolution vector graphics terminal by means of a computer program designed to allow the operator to interactively modify the model parameters. The initial stages of development of this model discussed in the first quarterly report had been restricted to a hypothetical satellite orbit at 90° inclination in the dawn dusk meridian plane and the initial computations included only the sunward component of the perturbation field at various altitudes.

During this second quarter the capabilities of this model have been extended considerably. The model is now capable of computing three vector components of the magnetic field arising from an assumed current system. The restriction on satellite orbits has now been almost entirely eliminated allowing the magnetic field components to be computed for virtually any satellite orbit over a range of inclinations and altitudes and having an arbitrary angle between the orbital plane and the earth-sun line. Figures 1 through 4 show sample plots of the model magnetic field output for a satellite at 500 km altitude with various orbital inclination angles. The main plots on these figures show three orthogonal components of the magnetic field each calculated at 94 separate observation points as a function of latitude. The solid curve is the sunward component, the dot-dash curve is the dawn-dust component and the dashed curve the vertical component. The input current system is a "classical" large-scale Birkeland sheet current model with downward directed currents in the high latitude

postmidnight and the low latitude pre-midnight portions and upward directed currents in the high latitude pre-midnight and low latitude postmidnight sectors. This current system is represented computationally in this example by 324 linear current elements as described above. The field-aligned currents are closed by N-S currents in the ionosphere at 110 km altitude. No E-W ionospheric currents have been included. The centers of the current sheets are located in the figures by the vertical lines at 61° and 70° invariant latitude. The latitudinal distribution of current intensity is plotted along the top of the main panel. The clock dial in the lower right-hand quadrant depicts the satellite orbit.

Two abstracts have recently been submitted for presentation at forthcoming scientific meetings. The purpose of these papers is to describe the magnetic modeling technique developed under this contract and to present some of the initial resulting magnetic perturbation signatures that have been derived from various model configurations of the polar Birkeland and ionospheric current systems. The first paper by Greer and Klumpar entitled "A Method of Calculating Magnetic Fields Due to Systems of Distributed Currents" has been submitted for presentation at the spring meeting of the American Geophysical Union and will primarily describe the modeling technique. The second paper entitled "A Technique for Modeling the Magnetic Perturbations produced by Field-Aligned Current Systems" by Klumpar and Greer will present results of several trial runs of the modeling program and attempt to show how these compare with the typical high latitude perturbations observed at Magsat. This latter paper will be delivered at the

Fourth Scientific Assembly of the International Association of Geomagnetism and Aeronomy in August 1981. Copies of these two abstracts are appended to this quarterly report.

III. PROBLEMS ENCOUNTERED AND RECOMMENDATIONS

No major problems have been encountered.

IV. PLANS FOR NEXT REPORTING INTERVAL

During the forthcoming quarter the development of data reduction software will continue. Programs to store selected portions of Magsat data on disc file for subsequent analysis and plotting are now being written. In particular, routines will be developed and integrated into our existing software to compute the geopotential magnetic field at Magsat and to subtract away this model field. The resultant observed perturbations in the scalar magnitude and each of the 3 vector components will then be plotted by interactive graphics routines designed to allow flexibility in plotting format.

Further development of the linear element field modeling procedure will take place during the next reporting period. The emphasis will be placed upon increasing the flexibility to choose more diverse initial current configurations.

A third major effort during the next quarter will be to obtain and bring into operation the grid cell modeling programs developed by J.L. Kisabeth. In the long term this grid cell modeling technique may be compared and contrasted to the linear elemental current model being developed at U.T.D. and discussed above. Ultimately some combinations

of the two techniques utilizing the relative strengths of each might yield the most realistic external field perturbations in the Magsat data.

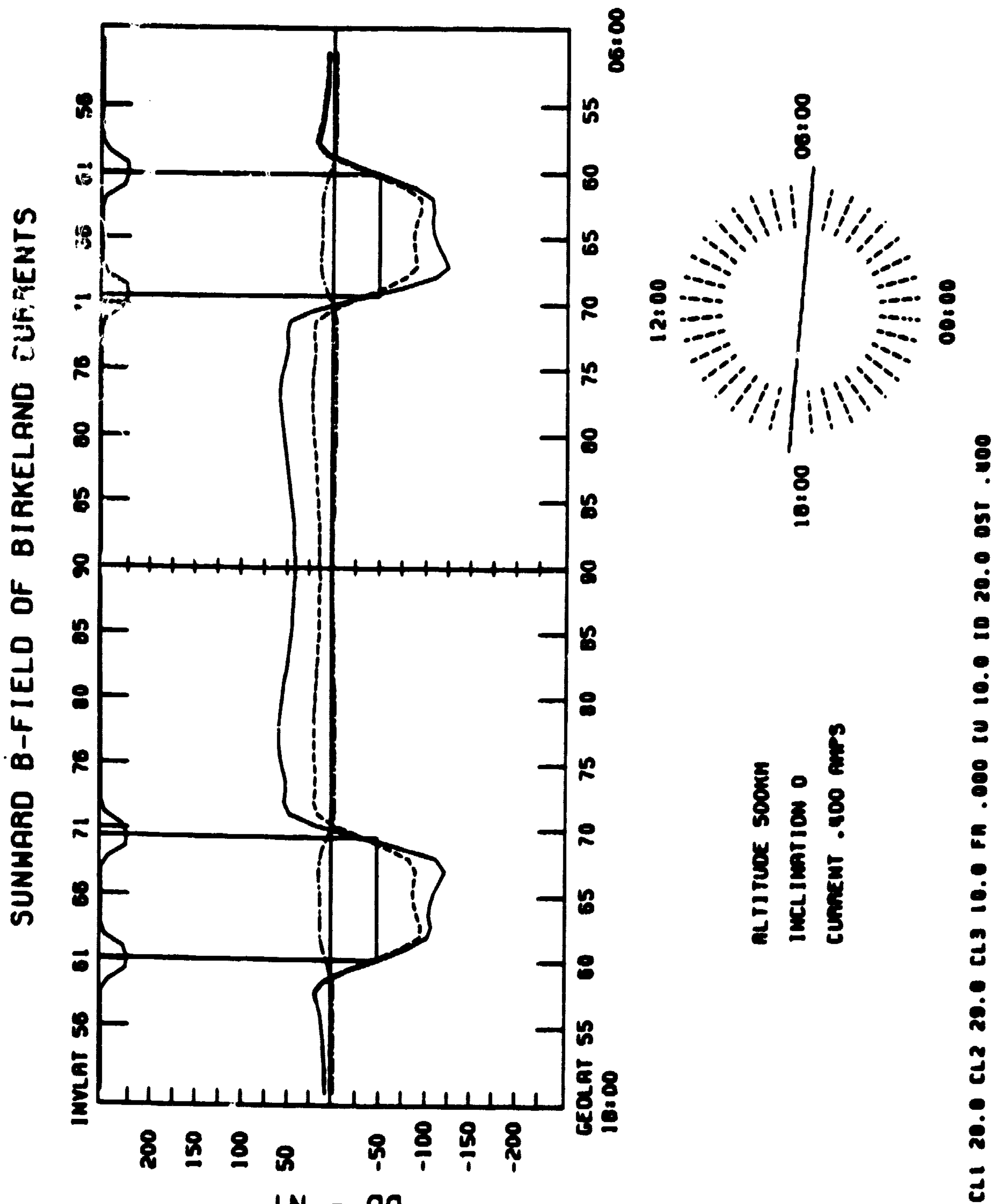
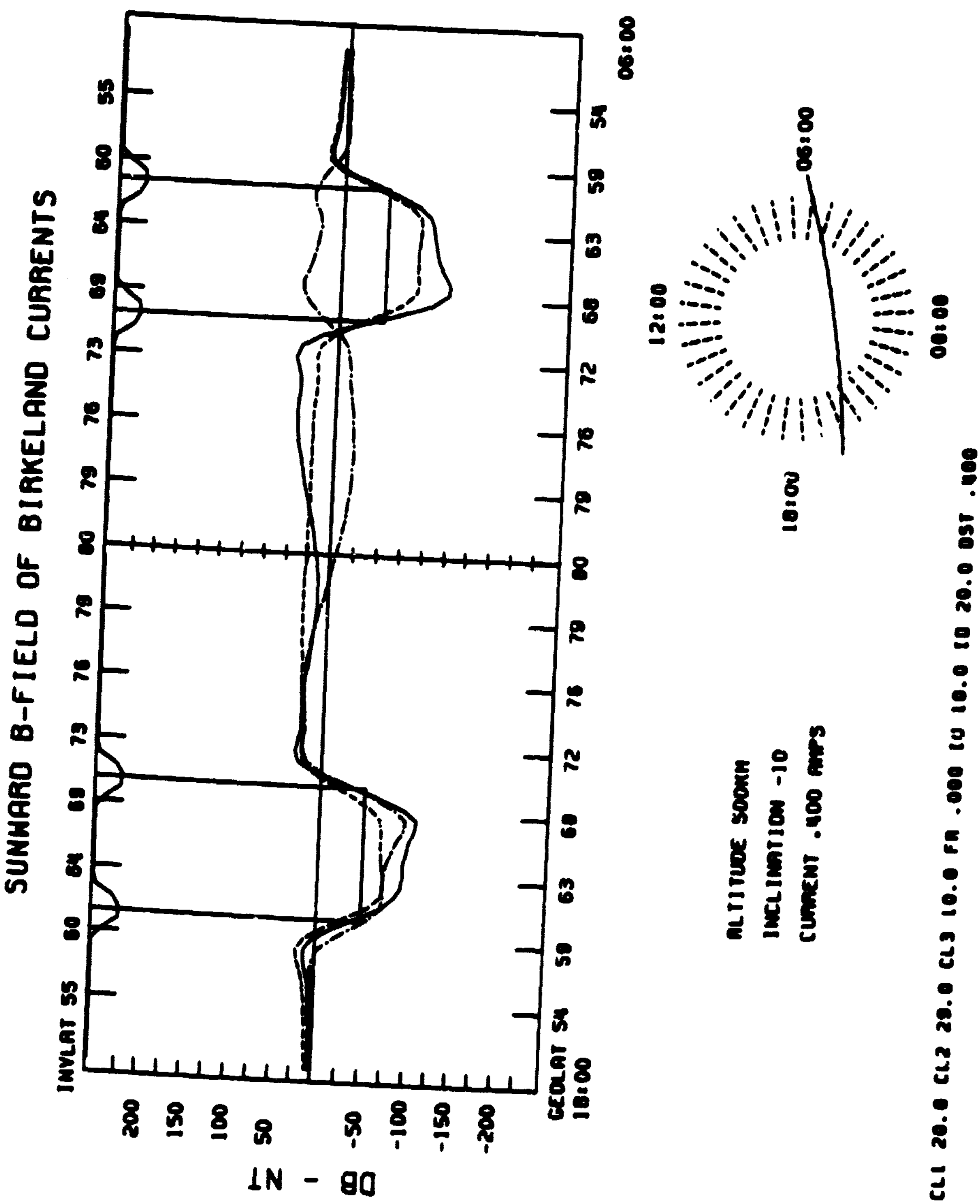

SUNWARD B-FIELD OF BIRKELAND CURRENTS
DB - NT
INVLAT
GEOLAT
ALTITUDE 500KM
INCLINATION 0
CURRENT .400 AMPS
CL1 20.0 CL2 20.0 CL3 10.0 FR .000 IU 10.0 ID 20.0 DST .000

FIGURE 1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GEOLAT 54
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06:00
12:00
00:00
ALTITUDE 500KM
INCLINATION -10
CURRENT .400 AMPS
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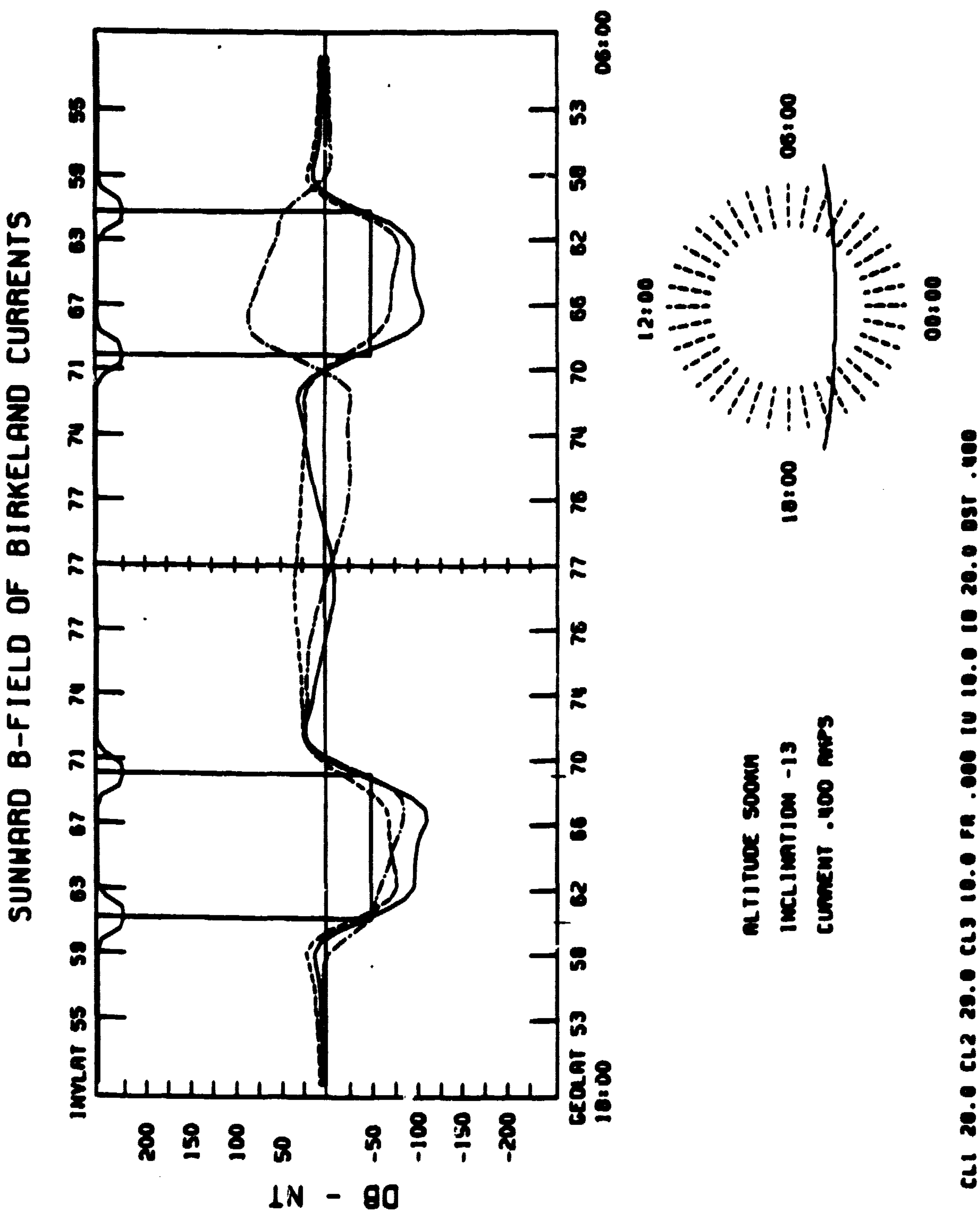
FIGURE 2


SUNWARD B-FIELD OF BIRKELAND CURRENTS
DB - NT
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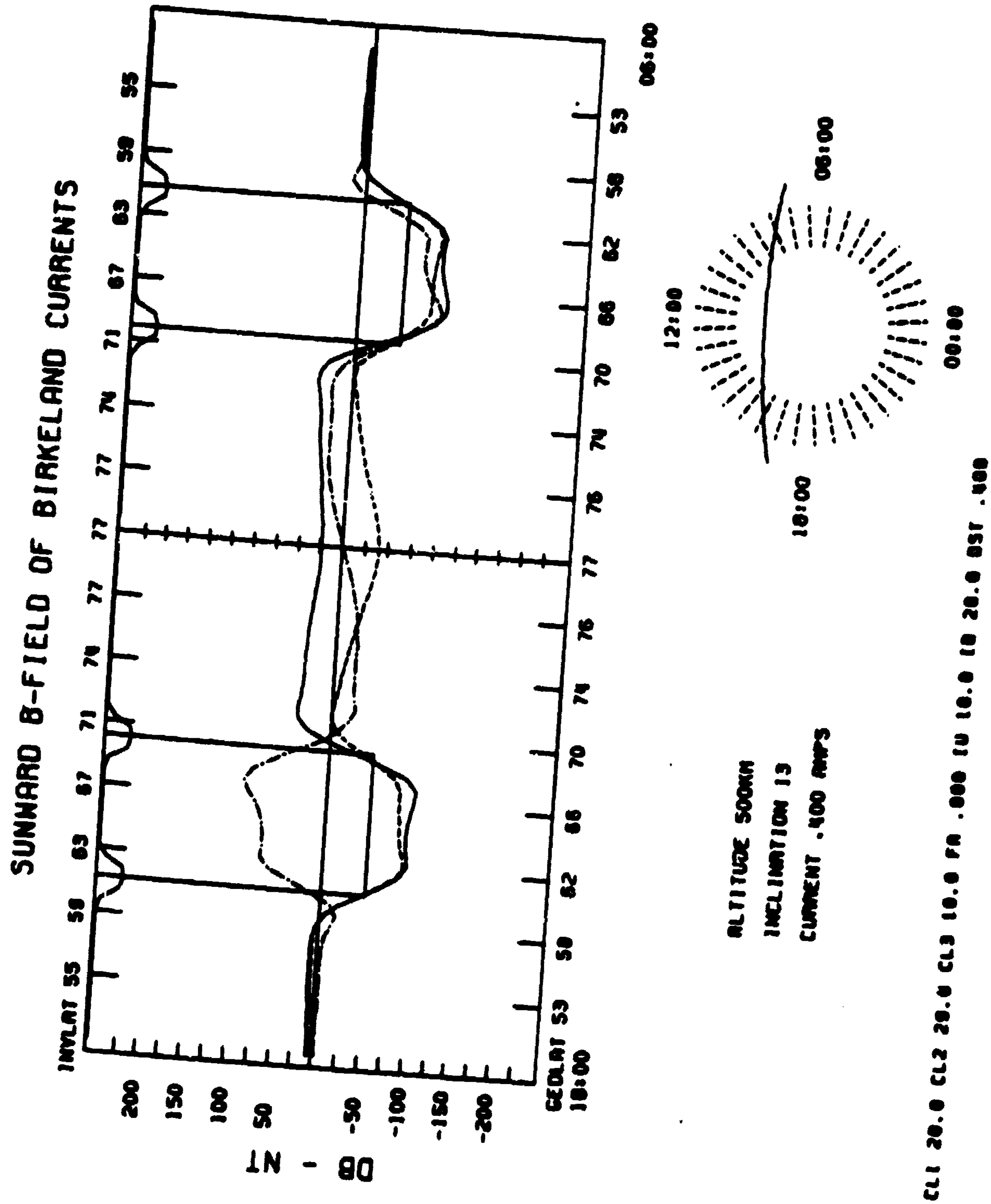
GEOLAT 53 58 62 66 70 74 76 77 76 74 70 66 62 58 53
18:00
06:00
12:00
00:00
ALTITUDE 500KM
INCLINATION -13
CURRENT .400 AMPS
CL1 20.0 CL2 20.0 CL3 10.0 FR .000 IU 10.0 ID 20.0 DST .000

FIGURE 3


SUNWARD B-FIELD OF BIRKELAND CURRENTS
DB - NT
200
150
100
50
-50
-100
-150
-200
INVLAT 55
58
63
67
71
74
77
77
77
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71
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63
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GEOLAT 53
18:00
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62
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74
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77
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74
70
66
62
58
53
06:00
12:00
06:00
00:00
18:00
ALTITUDE 500KM
INCLINATION 13
CURRENT .400 AMPS
CL1 20.0 CL2 20.0 CL3 10.0 FR .000 IU 10.0 IB 20.0 BST .400

FIGURE 4

APPENDICES

Abstracts of papers submitted for presentation at scientific meetings:

A. A Method of Calculating Magnetic Fields Due to Systems of Distributed Currents, submitted to American Geophysical Union, Spring Meeting, Baltimore, Md. May 25-29, 1981

B. A Technique for Modeling the Magnetic Perturbations Produced by Field-Aligned Current Systems, submitted for presentation at Fourth Scientific Assembly of IAGA, Edinburgh, Scotland, August 3-15, 1981

Appendix A

ABSTRACT

A METHOD OF CALCULATING MAGNETIC FIELDS DUE TO SYSTEMS OF DISTRIBUTED CURRENTS

D. M. Greer
D M. Klumpar (both at: Center for Space Sciences, University of Texas at Dallas, Box 688, Richardson, Texas 75080)

Electrical currents in the ionosphere and in the magnetosphere produce large amplitude magnetic field perturbations that are detected by the highly sensitive magnetometers on the polar orbiting MAGSAT satellite. This paper describes a computationally fast and mathematically simple method that has been developed and applied to modeling the magnetic field produced by the Birkeland current system. The technique allows the magnetic field of a distributed current system to be calculated by representing such a system with an arbitrary number of hypothetical linear current elements. The facility of this method derives from the use of an analytical expression for the magnetic field of a straight current filament having an extended and smoothly varying current density. The cross sectional current density profile of such a filament looks somewhat like a square wave pulse, of arbitrary width, with rounded corners. Thus the system is free from unwanted discontinuities and the field component in any direction and at any point in the model space is easily calculated. Magnetic perturbations typical of those encountered at auroral latitudes by MAGSAT are produced by the model when realistic current configurations are chosen.

SUBMITTAL INFORMATION

1. Spring Meeting
2. Applying as student member.
3. Corresponding address:

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4. SM
5. Field-Aligned Currents
6. P (Poster)
7. None
8. a) Accounting Department
   University of Texas at Dallas
   Box 688
   Richardson, Texas 75080

   c) Student rate applicable.

9. C (Contributed)

Appendix B

A TECHNIQUE FOR MODELING THE MAGNETIC PERTURBATIONS PRODUCED BY FIELD-ALIGNED CURRENT SYSTEMS

D.M. Klumpar and D.M. Greer (Center for Space Sciences, University of Texas at Dallas, Richardson, Texas 75080, U.S.A.)

This paper presents results of a computational procedure that utilizes various assumed distributions of ionospheric and field-aligned currents to model magnetic perturbations observed at high latitudes from the polar orbiting MAGSAT satellite. The highly sensitive vector magnetometers on MAGSAT repeatedly observe magnetic field perturbations on essentially every transit of the high latitude ionosphere. These perturbations, with field components lying predominantly in the magnetic East-West direction, are customarily viewed as the signatures of oppositely directed paired sheets of electrical current flowing parallel to the geomagnetic field. These paired current sheets are typically regarded as being highly restricted in latitudinal extent and elongated in magnetic longitude. The model developed under this research utilizes a computationally fast and mathematically simple technique that allows the magnetic field of a distributed current system to be calculated by representing such a system by an arbitrary number of hypothetical linear current elements. The facility of the technique derives from the use of an analytic expression for the magnetic field of a linear current element having an extended and smoothly varying cross sectional current density; thus eliminating unwanted discontinuities. Magnetic perturbations typical of those encountered at auroral latitudes by MAGSAT are produced by the model when realistic current configurations are chosen. Direct comparisons between the model field perturbations and those measured by the MAGSAT magnetometers permit more refined models of the Birkeland currents to be developed.

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2. ER

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4. ---

(a) Oral presentation

Submitted to Fourth Scientific Assembly of IAGA, Edinburgh, August 3-15, 1981